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physical and the psychical does not seem to help matters in a sophisticated day as the interaction of body and mind on the occasion of knowing comforted Descartes. When sense-data, and all psychological processes, are regarded as completely mental, and added to this is the equivalence of the mental, the psychic, and the conscious; when knowing, start and terminus, is in this psychical world, and by common assumption whatever else there is (if there be anything else) is wholly alien to thought; then, surely, the choice is between subjectivism and despair. When we feel compelled to prove the existence of an external world, while the scientist and the man on the street alike assume its existence and take for granted some acquaintance with and knowledge of it, one can not resist the conclusion that there is something artificial and spurious in the problems generated by the dual view of existence.

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ESTIMATION OF CENTIDIURNAL PERIODS OF TIME: AN EXPERIMENTAL INVESTIGATION OF THE TIME SENSE

Problem and Conditions of the Experiment.—The aim of this investigation was to determine the accuracy and steadiness of judgment in estimating small portions of a day. The experiment was performed at Pittsburgh, December 27 to 29, 1917. Thirty-three subjects took part, all well trained in psychological observation; all but five were members of the American Psychological Association, through whose courtesy the names of the subjects with standard time assigned to each were printed and distributed before the experiment started. In addition to the subjects themselves about 75 persons assisted the experimenter in absorbing the sound waves.[1]

The conditions of the experiment were as follows: The subject was directed to stand up and talk without intermission during a stated interval of time. The choice of topic was left entirely to the option of the subject, and he was free to speak with or without notes, to read aloud, to illustrate by charts, chalk, *etc.* The period of time assigned was 15 minutes in case of 25 subjects, 10 minutes for 5 subjects, 5 minutes for 1 subject, while 2 were left free to choose their own period. It will be observed that the 15-minute period is 1/96 part of a day, or 0.01041666. This can readily be reduced to the 1/100 part (0.01) required by the experiment by application of the Spearman foot-rule.

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[1] The writer wishes cordially to thank his subjects, some of whom came from a considerable distance at great personal inconvenience to participate in the experiment; he wishes also to express special gratitude to his assistants for their faithful cooperation, without which the auditory shock might at times have disrupted the atmosphere and demobilized the investigation.

Results.—For the 25 subjects whose standard period was 15 minutes the average time was 23.23 minutes, M.V. 3.1415928; for the 5 with standard 10 minutes, average 14.92, M.V. 5.280; for standard 5 minutes, average 6, M.V. 0; for free reproduction, average 23.13, M.V. 1.917. The C.E.'s are + 8.23, + 4.92, + 1, and 0, respectively, or, reducing to proportional parts, 1.548, 1.492, 1.2, 1, for each of the four cases. It will be noted that those who were free to reproduce any period of time succeeded in reproducing it exactly. Of the others, in every case the period was exaggerated, but the longer periods were lengthened, not merely absolutely more, but *proportionately more,* than the shorter. This is clearly a confirmation of the speeding-up principle, or law of cumulative enthusiasm. The disparity between the 15-minute and 10-minute periods would be greater if we leave out of account one of the 10-minute subjects whose actual time was more than twice as long as that of the others, or 23.88 minutes, indicating some misinterpretation of the instructions.

Distraction.—The effect of distraction was tested as follows: At the end of 20 minutes an assistant, Y., seated behind the subject gave two faint taps on the table with a pencil; this signal was repeated somewhat more loudly at intervals of 2 minutes, the increase in intensity of the distraction following precisely the Weber-Fechner Law. This would have necessitated the use of a 250-gram dynamite detonation at the end of 40 minutes; fortunately, however, only one of the subjects came dangerously near this limit. The distraction effect was applied to 14 subjects, whose average time was 26.52 minutes, M.V. 2.1234, while that of normal subjects was 19.05, M.V. 4.111. In other words, the effect of distraction was to *lengthen the time* and increase the C.E., while it decreased the M.V. Calculating the distraction effect in dynes, it was found that had this disturbing sound been omitted, the average time of 13 of these 14 subjects would have been raised to 50 minutes precisely, *i. e.,* to the normal lecture period. It was impossible to make the correction for the fourteenth subject, whose *vis loquendi* was so great that without the distraction his period would have extended indefinitely, or at least till complete exhaustion.

Contrast and Habit.—The influence of contrast was investigated by alternating 15-minute and 5-minute periods. The results were entirely negative. The influence of earlier upon later subjects may be determined by comparing the average of the first ten with the last ten. These are 22.22 and 24.99, respectively. This was at first thought to indicate a cumulative latency effect. It is more probably explained, however, by habituation. As the later subjects were present during the earlier experiments, they doubtless grew accustomed to the distraction signals and were less disturbed by them than the earlier subjects.

An even more striking effect of habit was observed in connection with the free judgments. The 2 subjects Th. and So. were allowed to select their own time absolutely without restriction. They might, *e. g.*, have spoken for three seconds or for three whole days. Had they come first in the list of subjects they would of course have spoken for exactly 50 minutes, the customary length of lecture periods. As a matter of fact, their average time (23.13 minutes) was almost exactly that of the average for the 15-minute group—nearer, in fact, than could be measured by any watch chosen at random from the entire group of observers. This indicates clearly the effect of habit upon the duration of laryngomotor processes.

Influence of Previous Training.—The effect of general training was brought out by comparing the judgments of members of the Association with those of non-members. The latter, while they were all well trained in laboratory technique, introspection, and general behavior, were considerably younger and less desiccated than the Association members. Contrary to expectation, it was found that the judgments of non-members were *more accurate and more steady* than those of members, the averages being 17.76 and 24.60 with M.V. of 2.468 and 4.321, respectively. Part of this difference may doubtless be accounted for by the deeper emotional effect of the distraction taps upon less sophisticated natures. But if we eliminate this by the method of least squares a difference of 3.33 still remains, which is 9.41 times the probable error. This forces us to the significant conclusion that *accurate appreciation of time diminishes directly with age and psychological training and inversely with the intelligence quotient I.Q.*

Influence of Stereokinesis.—An attempt to measure the influence of the distance traveled by various subjects upon their judgments brought out no significant correlation whatsoever. It is interesting, however, to note that the subject who had traveled the second furthest distance gave the shortest actual judgment of the 15-minute period, 15.02, while the subject who had traveled the shortest distance (excluding those from Pittsburgh itself) gave exactly twice this: 30.04.

Temperature.—The experimenter was able to test the influence of warmth and cold upon the time estimates by the following device, credit for which is due to the Pullman Company. The weather at the time of the investigation was unusually cold, but the research rooms were well heated. At one session the experimenter arranged so that the steam heat was turned on full, while the doors and windows of the room were tightly closed. At the next session he turned off the steam and opened the windows wide thirty minutes before the experiment began. No significant difference appears in the average times of these two sessions. This is readily explained by the fact that in a cold room the natural heat of the speaker radiates out more freely, raising the temperature in his immediate vicinity far above that of the warm session. The temperature was meassured by means of a clinical thermometer suspended by the Hipp on a knife-edge 2 mm. from the subject's right ear.

Topical Classification.—Since the subjects were free to choose their own topics of discourse, it was possible to compare the estimates of time based upon different classes of topics. The topics were classed as laboratory reports, theoretical discussions, mental tests, educational psychology, and nonsense syllables. It was at first proposed to dichotomize the papers into fact and fiction, but this proved impracticable, since most of them contained a certain modicum of each. On the basis finally selected the judgments range in the following order: theory 21.2 minutes, education 22.3, nonsense 23.4, tests 25.6, laboratory 27.8. Comparing the procedure with charts and procedure without charts, it was found that the explanation of charts *lengthened* the time by nearly 5 minutes (4.998). If this correction be made in the classification of topics it would reduce the time for explaining laboratory experiments by the above amount, making it the lowest of all, while it would not alter the time for describing tests, since in discussing tests charts must always be used or the topic reduces at once to the class of nonsense-syllables. The conclusion deduced from this is that laboratory experiments should be explained by auditory rather than visual presentation, while mental tests should be applied with no attempt at elucidation.

Control Experiments.—Our final step was to compare the subjects' estimate of time with the estimate by the experimenter and his assistants. Two methods were employed—introspection and behavior. In the first the procedure was simply to write down immediately after each speaker had finished the number of minutes the hearer judged had been consumed in the phonetic automatism. Besides the writer two assistants took part in these judgments—the only participants who were not biased by having acted as subjects themselves. The estimates of the three observers agree singularly with each other, but they deviate even further from the objective time than does the estimate of the subjects. Thus one paper, standard 10 minutes, reproduction time 17 minutes, was estimated by the observers as 2 hours, 49 minutes, P.E. 35 minutes, while another paper, standard time 15 minutes, reproduction 28 minutes, was estimated at 13 minutes, P.E. 1.5 minutes. Evidently the estimate of the auditor is tremendously influenced by certain obscure physical factors, such as heaviness, brilliancy, sparkle, *etc.* These factors will be examined in a later investigation.

The behavior method consisted in noting the attitude of the audience as a whole, counting the number of yawns and snores, restless movements and furtive exits, reading irrelevant material, *etc.;* also by measuring the energy of wrist movements and the intensity of the compalmovibratory sounds at the end of each speech. The former manifestations correlate well with the introspective estimates; the latter do not correlate at all. It may be suggested that the latter disagreement is due to the fact that vigorous applause may either be generated by the content of a speech or it may be a conditioned reflex stimulated by relief at its termination. There is some question, however, whether this hedonic explanation is admissible in a behavioristic study. The salivary reflex and knee-jerk were not tested.

Summary.—The most important results from this investigation are: (1) The general tendency to *overestimate* the period. This correlates with the well-known observation that while married men do not actually live longer than single men, the time *seems* much longer to them. (2) The importance of *distraction* as a regulator of time appreciation. This confirms many observations which have demonstrated that the striking distraction afforded by an alarm-clock produces greater precision in building up temporal associations with an eight o'clock lecture or a six o'clock train. (3) The effect of *training.* While distraction increases the accuracy of estimation, practise decreases it. In particular, the habit of lecturing to young and naïve audiences tends to minimize conciseness and lucidity. In certain cases the best and perhaps the only sure corrective is the well-known apparatus designed in 1792 by Monsieur Guillotine. (4) Perhaps the most noteworthy fact brought out by our research is the tremendous disparity between a speaker's own estimate of time and that of his auditors. We may denote the subject's appreciation of the period by "Function *a*" (*Fa*), while the estimate made by his audience is represented by a constant (k) times the variable e. An exact measure of the performance as a whole is denoted symbolically by the expression *F.a.k.e.*

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